A probabilistic plume model (PPM) of shallow-deep convection

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Jargon

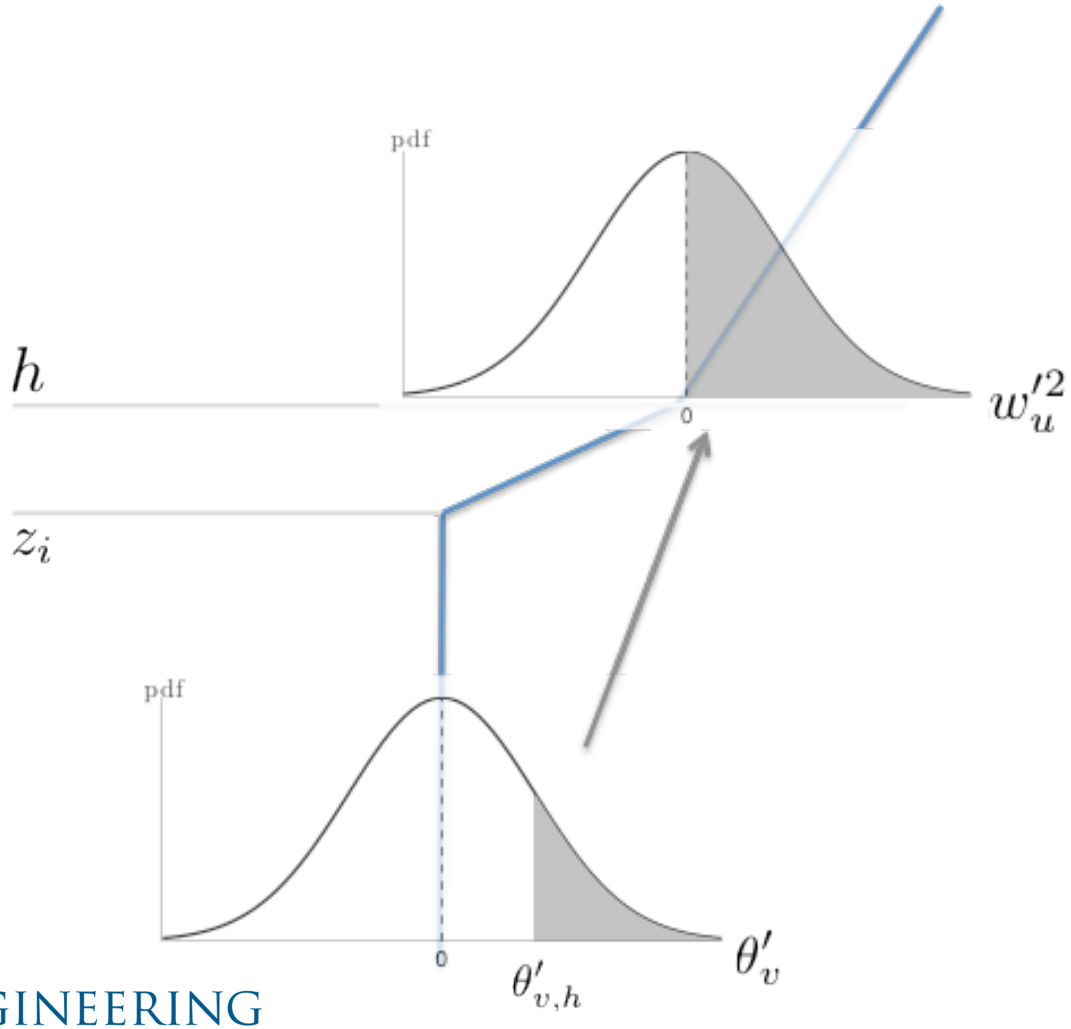
Shallow convection subdivided into 2 subgroups:

Forced shallow convection:
generated by *non-buoyant* updrafts,
very small vertical extent
(few tens or hundreds of m)
Important radiative effect

Active shallow convection:
generated by *buoyant* updrafts.
Tower-like but not as tall as deep convection.
Radiative and thermodynamic effects

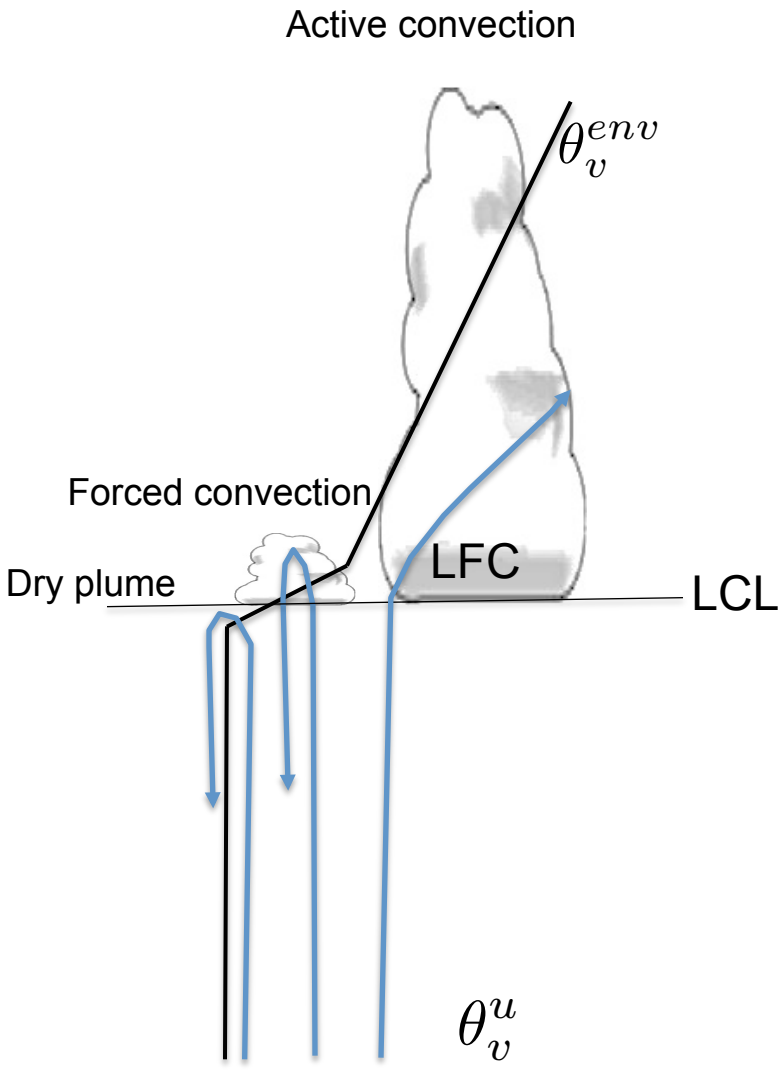
Probabilistic approach

- **Assume a Gaussian pdf near the surface based on similarity with H, lE and w***



2) Moist case: new entrainment formulation

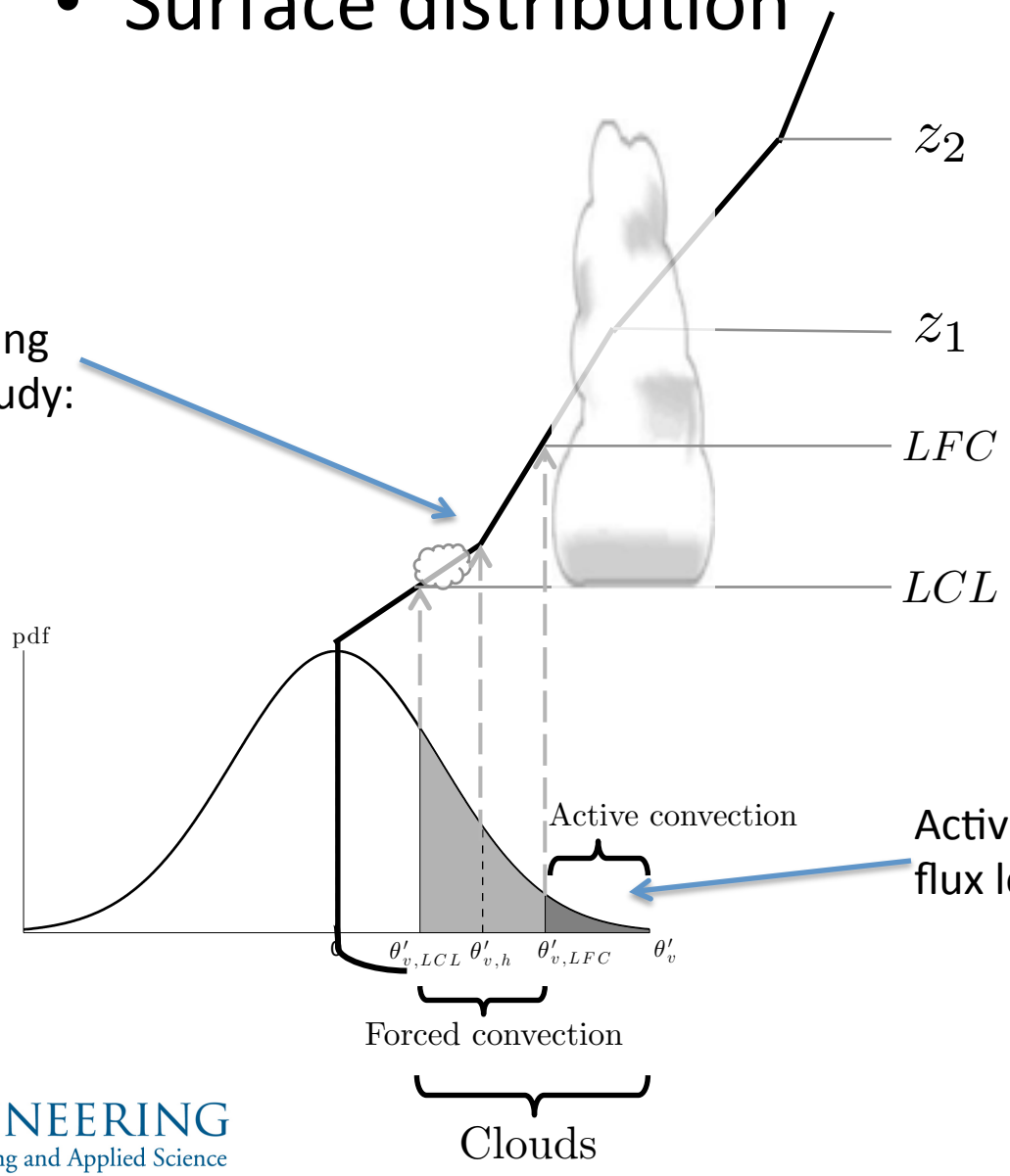
Virtual Potential temperature is indicator of buoyancy



2) Moist case: new entrainment formulation

- Surface distribution

All updrafts generating entrainment are cloudy: added latent heat



Active updraft mass flux leaving the system

2) Moist case: new entrainment formulation

$w_u = 0$

Typical convection scheme:

a) $$\frac{\mathrm{d}\phi^u}{\mathrm{d}z} = -\epsilon(\phi^u - \phi^{env})$$

b) $$\frac{1}{2}\frac{\mathrm{d}w_u^2}{\mathrm{d}z} = c_1 B(z) - c_2 \epsilon w_u^2$$

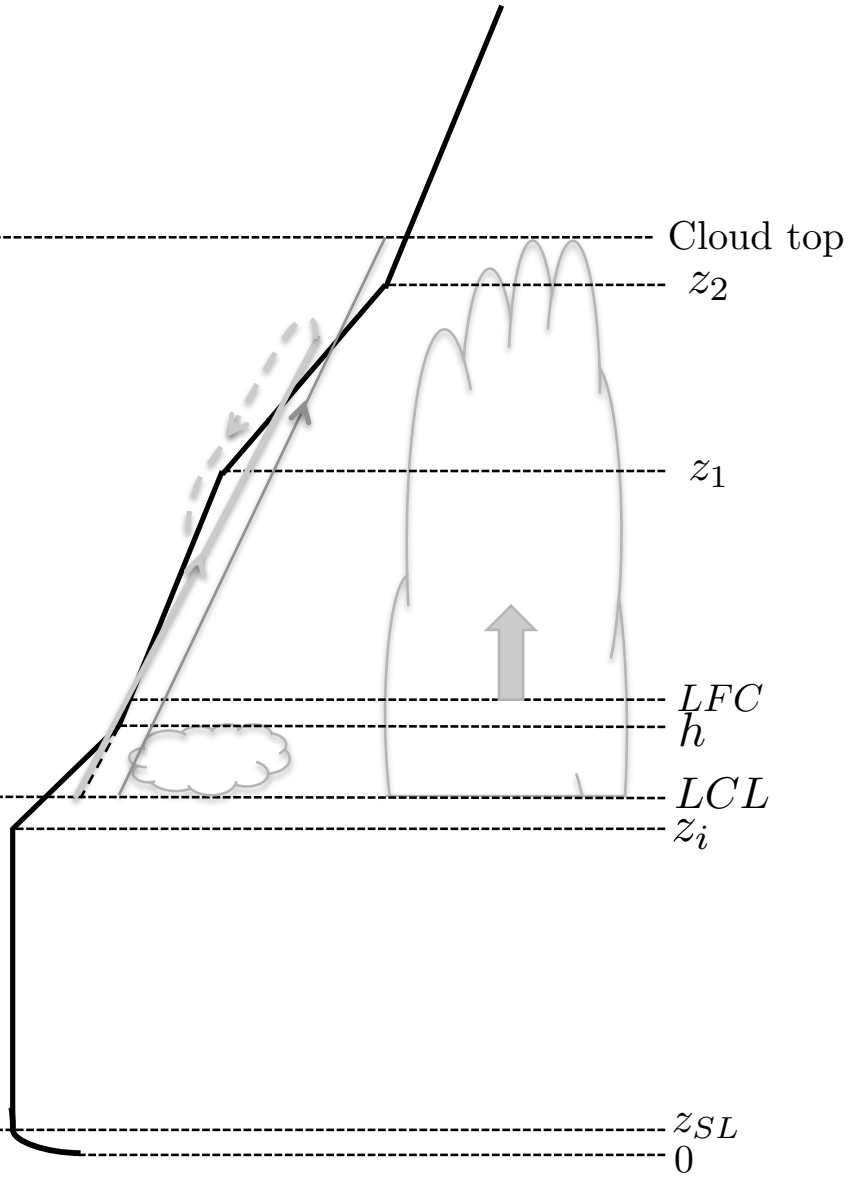
c) $$\frac{1}{M_u^{\text{active}}}\frac{\mathrm{d}M_u^{\text{active}}}{\mathrm{d}z} = \epsilon - \delta$$

Mixed layer scheme:

a) $$\frac{\mathrm{d}\phi^u}{\mathrm{d}z} = -\epsilon(\phi^u - \phi^{env})$$

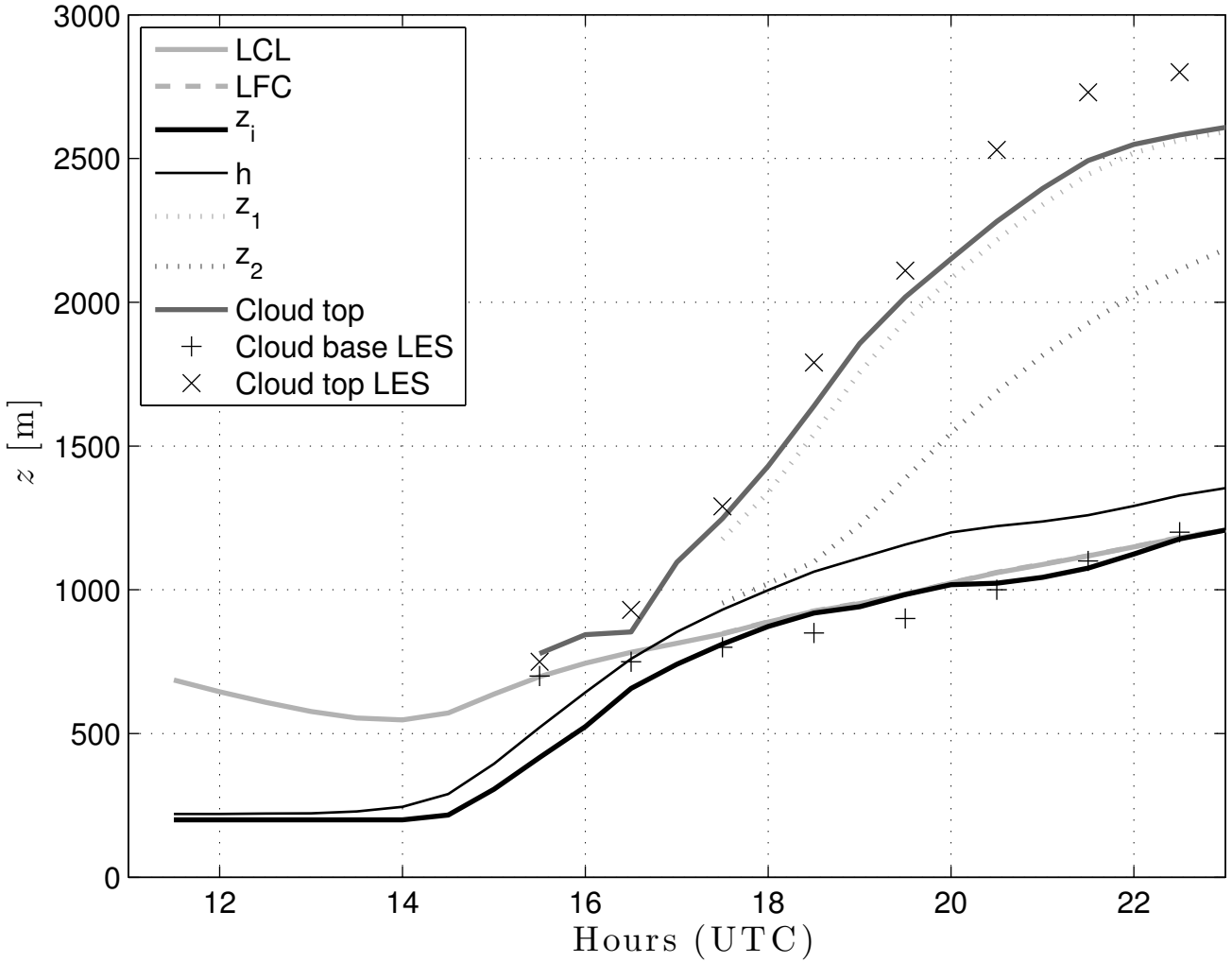
b) $$\frac{1}{2}\frac{\mathrm{d}w_u^2}{\mathrm{d}z} = c_1 B(z) - c_2 \epsilon w_u^2$$

c) $$M_u = \rho\overline{f_u w_u}^u = \int_0^\infty \max\left(w_u(z), 0\right) N(\theta_v')\, d\theta_v'$$



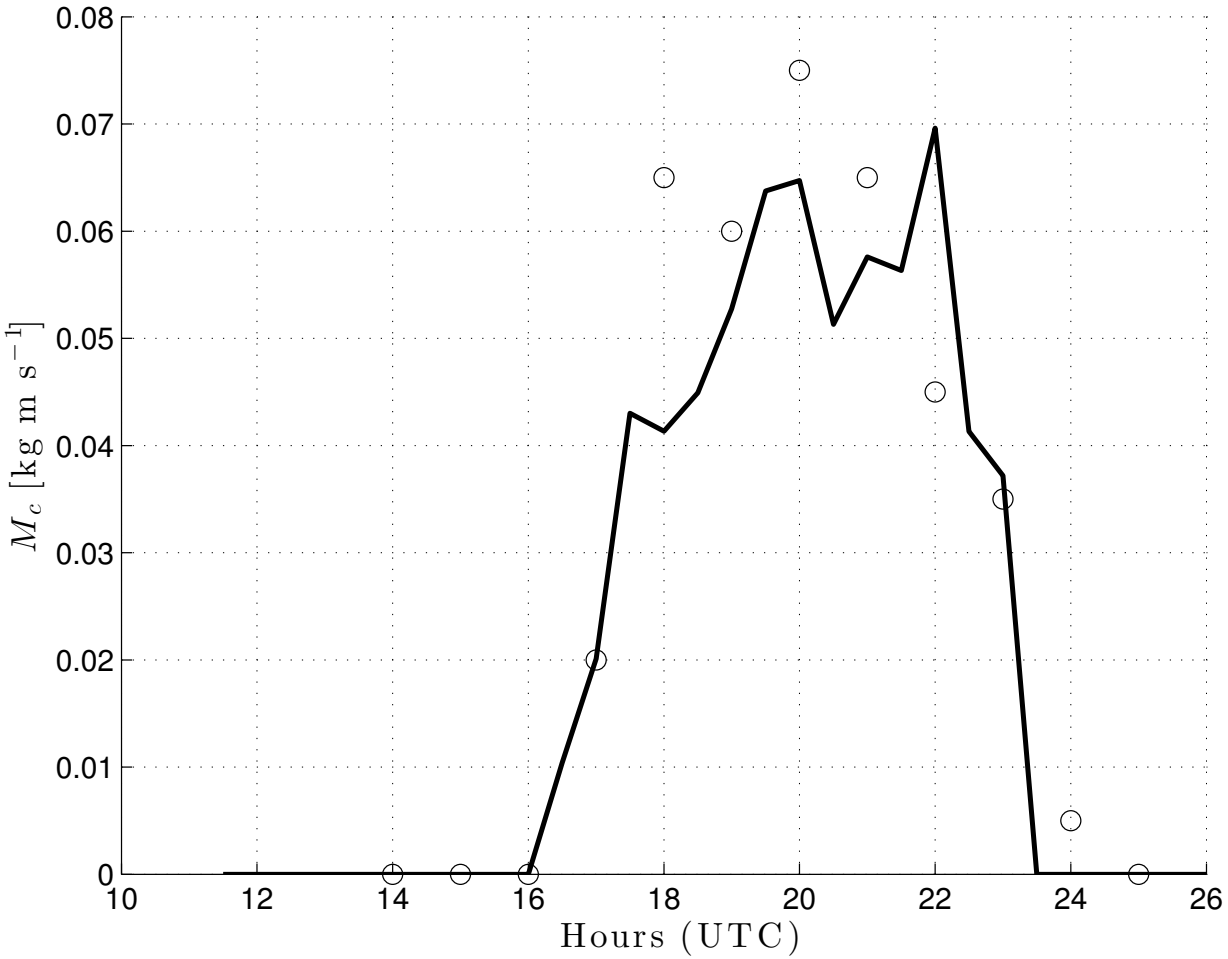
Gentine et al., 2013, JAS, part II

2) Moist case: ARM June 1997



Gentine et al., 2013, JAS, part II

2) Moist case: ARM June 7



Mass flux at cloud base

Gentine et al., 2013, JAS, part II

Extension to deep convection: parameterization

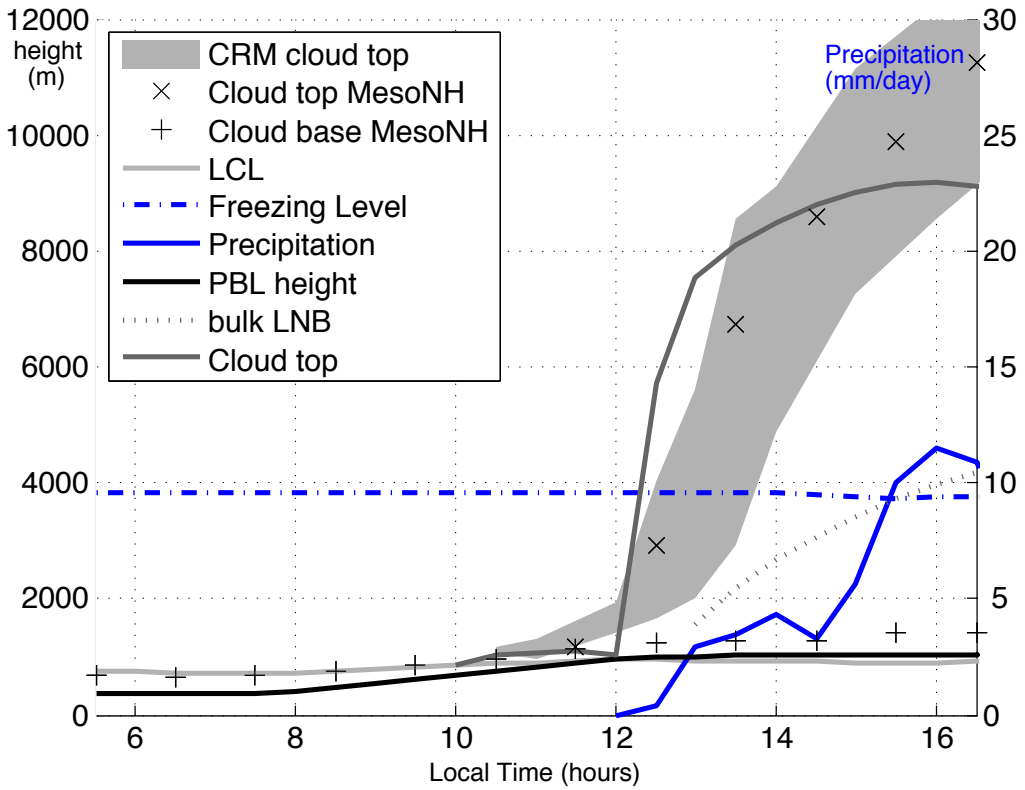
Addition of:

- **Ice** (Bryan and Fritch 2004) – piecewise linear (made numerically stable with tanh) between water vapor saturation and 0 °C
- **Precipitable water**: a simple liquid+ice threshold a la (Hohenegger and Bretherton 2011)
- **Precipitation** (efficiency of precipitable water dependent on cloud thinkness Emanuel 1991)
- **Unsaturated downdraft**
- **Scaling of lateral entrainment** with convection circulation (cloud depth if rain):

$$\epsilon = \underbrace{\frac{c_\epsilon}{z}}_{\text{shallow scheme}} \underbrace{\frac{LCL}{\text{cloud top}}}_{\text{deep convection scaling}}$$

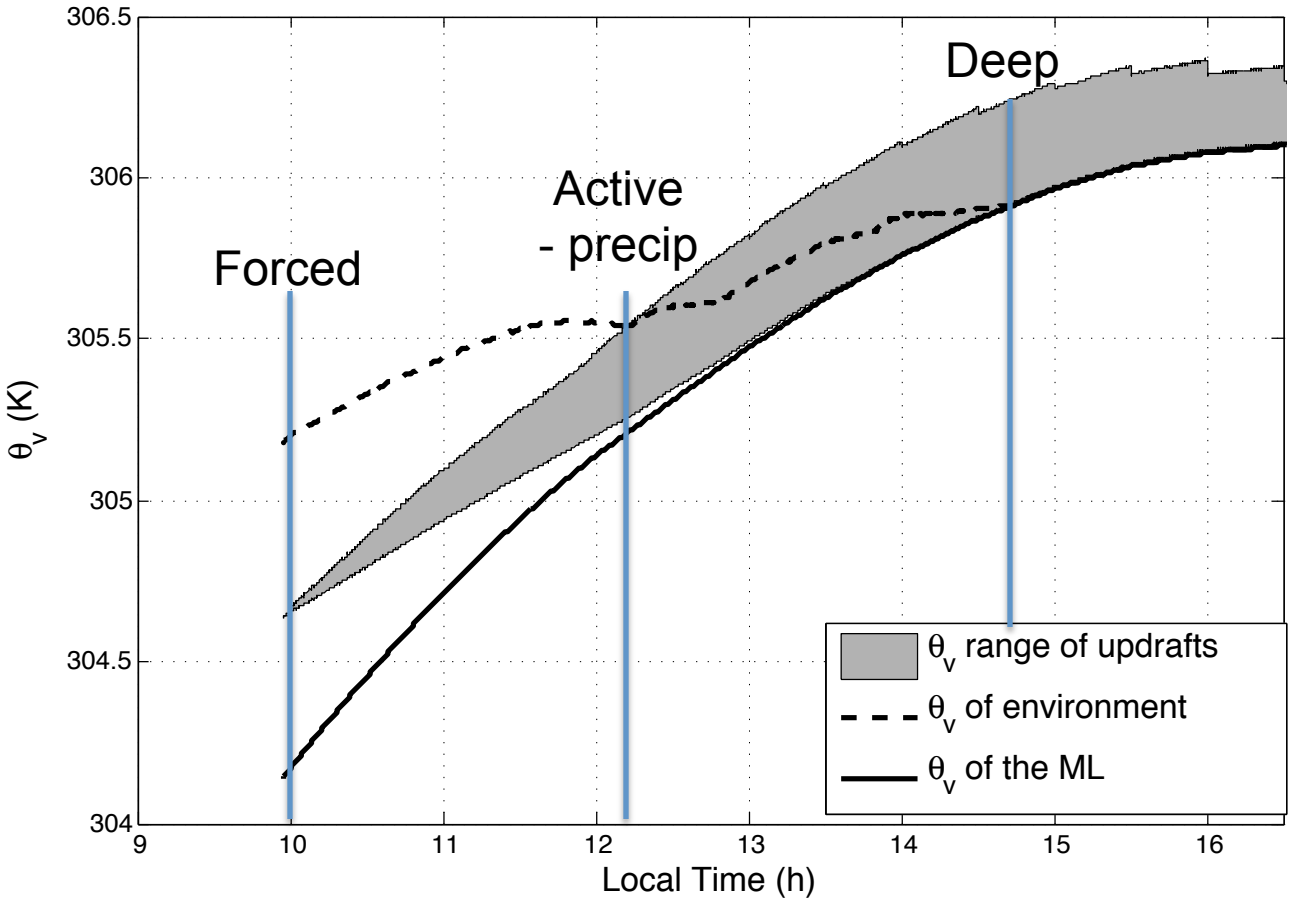
- So far no changes in surface pdf, next step (cold pools with Zhiming Kuang)

Deep convection: ARM SGP June 21 1997



Test case of ARM SGP Guichard (2004): deep convection over land SGP
Good timing of convection (shallow and deep)
Too shallow: no cold pools

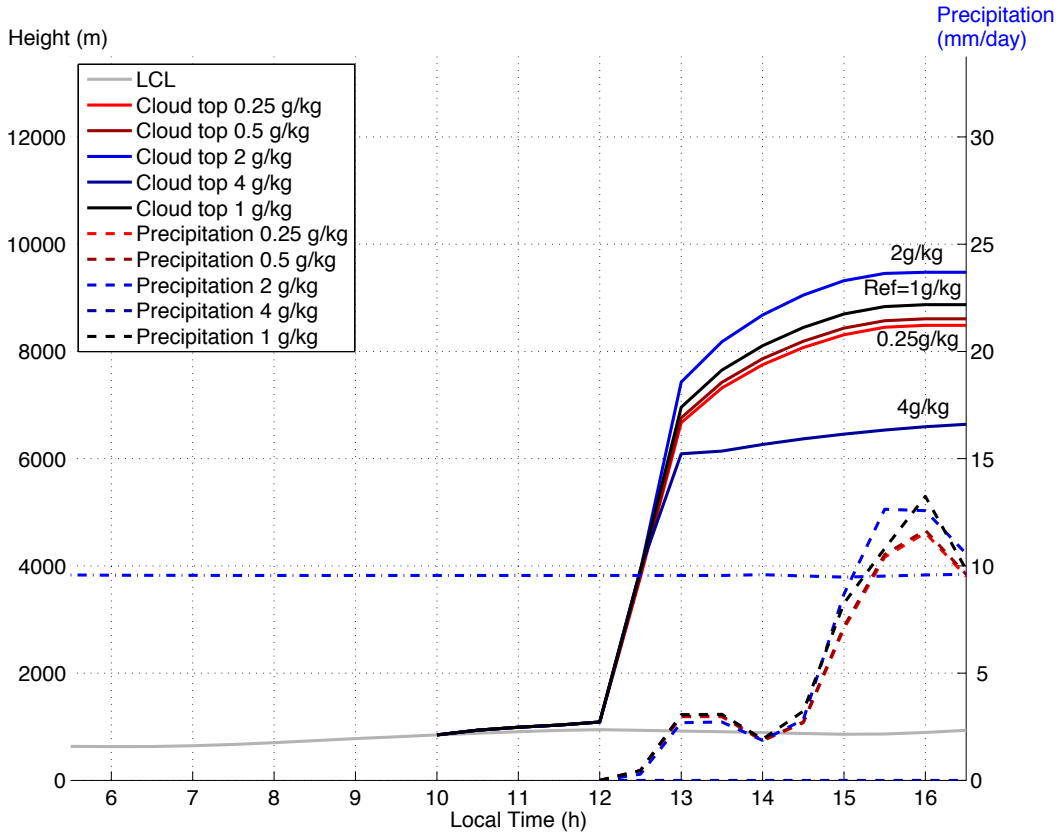
Why do we trigger: ARM SGP June 21 1997?



Role of pdf of updrafts
3 regimes: forced, active shallow, deep.
This is our definition of deep, one among many

D'Andrea et al., 2013, JAS, (submitted)

Sensitivity to microphysics (autoconversion threshold)



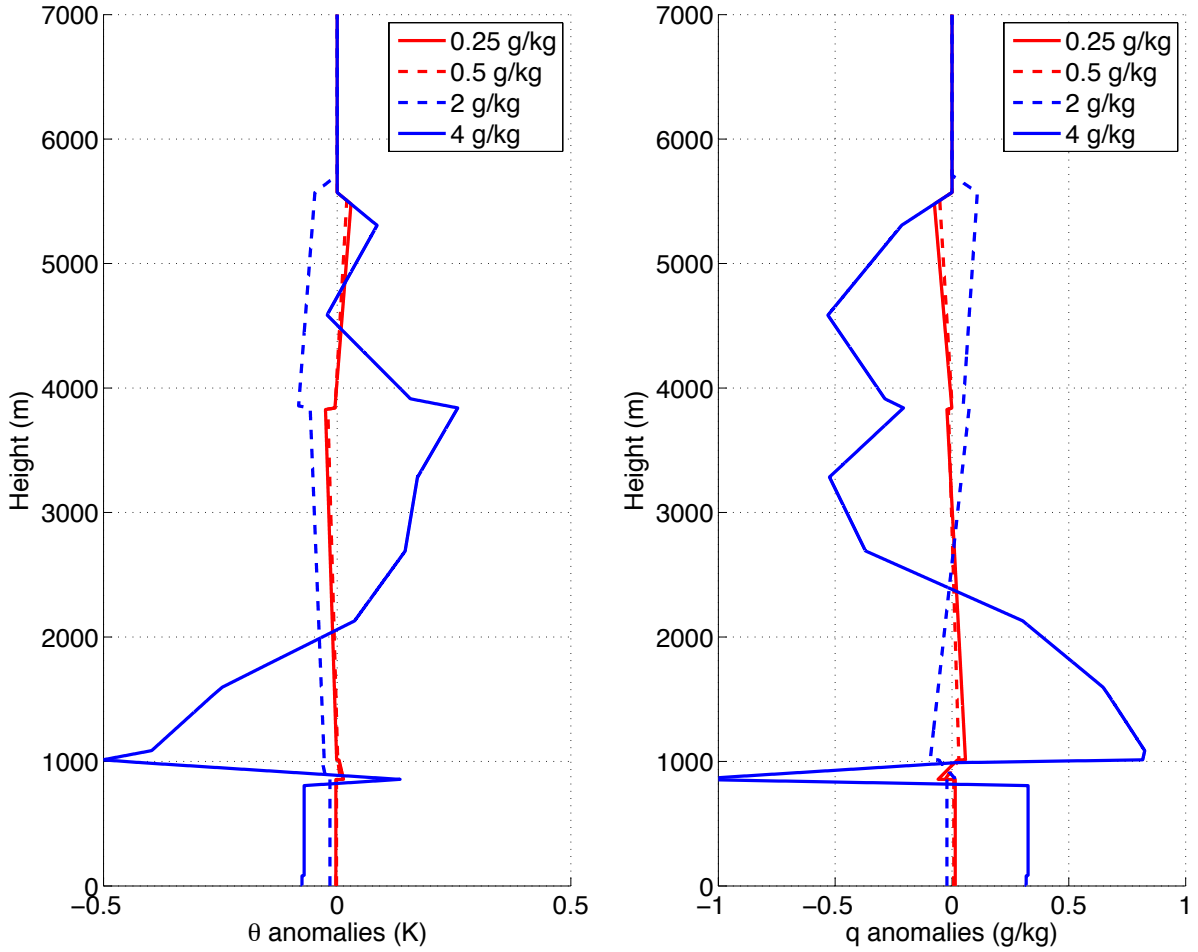
Higher autoconversion threshold for rain (0.25 to 2g/kg):

- less precipitable water, higher clouds (more humid profiles), near similar surface rain, no change in timing (trigger independent of precip – at east in the model), no change in moist adiabat

Very high autoconversion threshold for rain (4g/kg):

- all rain evaporates before reaching the ground, lower clouds (stuck in congestus phase, no surface rain, no density current => no entrainment scaling/organization)

Sensitivity to microphysics (autoconversion threshold)



Higher autoconversion threshold for rain (0.25 to 2g/kg):

- profiles more humid in the inversion, drier the cloud layer, colder cumulus layer

Very high autoconversion threshold for rain (4g/kg):

Very humid subcloud layer (rain reevaporation), more humid cloud layer, drier inversion